

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

(7)

# (12) UK Patent Application (19) GB (11) 2 332 124 (13) A

(43) Date of A Publication 09.06.1999

(21) Application No 9725890.9

(22) Date of Filing 05.12.1997

(71) Applicant(s)  
British Broadcasting Corporation  
(Incorporated in the United Kingdom)  
Broadcasting House, LONDON, W1A 1AA,  
United Kingdom

(72) Inventor(s)  
John Thomas Zubrzycki  
Richard Harold Evans

(74) Agent and/or Address for Service  
Reddie & Grose  
16 Theobalds Road, LONDON, WC1X 8PL,  
United Kingdom

(51) INT CL<sup>6</sup>  
H04B 7/08, H04L 1/06

(52) UK CL (Edition Q)  
H4L LDDRCX LDDSX  
U1S S2222

(56) Documents Cited  
GB 2259430 A GB 2237706 A EP 0683571 A2  
EP 0575746 A1 WO 96/08088 A1 WO 91/20142 A1  
US 5541963 A US 4278978 A

(58) Field of Search  
UK CL (Edition P) H4L LDDRCP LDDRCW LDDRCX  
LDDRQ LDDRQX LDDSX  
INT CL<sup>6</sup> H04B 7/04 7/08, H04L 1/02 1/04 1/06  
Online: WPI

(54) Abstract Title  
Digital radio communication system

See 6.

(57) A digital radio communication system has a mobile transmitter (2) which transmits error protected digital data on a plurality of radio carriers to a plurality of receiving antennas (4). The receiving antennas are placed around an area in which the transmitter is to be used. A summation means is coupled to the receiving antennas and the signals received by them are combined to produce an output signal. The signal pulse from each receiving antenna to the summation means include delays (12, 14) to reduce the effect of interference between signals received on two or more receiving antennas. A multi-carrier receiver (10) is coupled to the summation means to receive the output signal and it includes an error protection decoder to decode the original digital data.

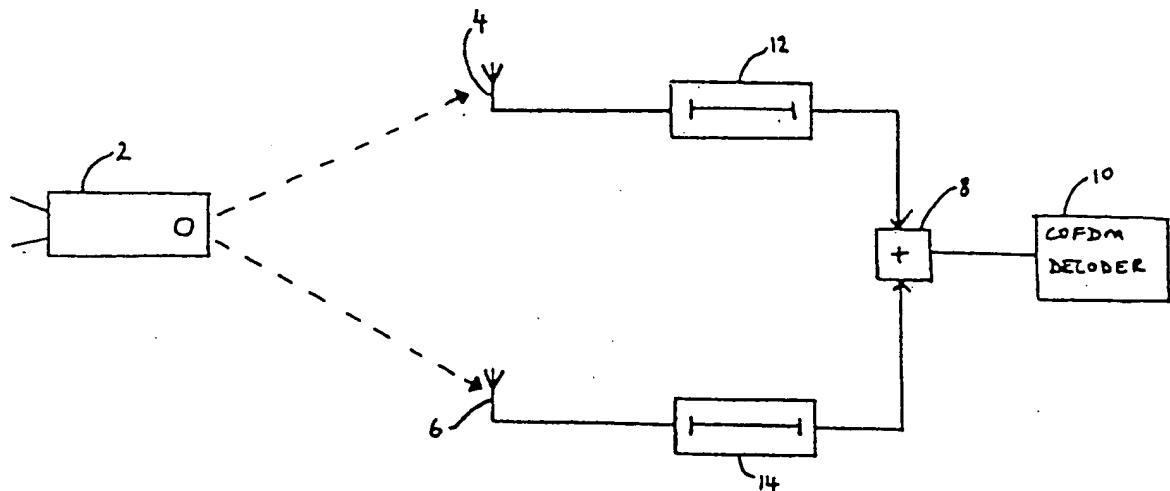
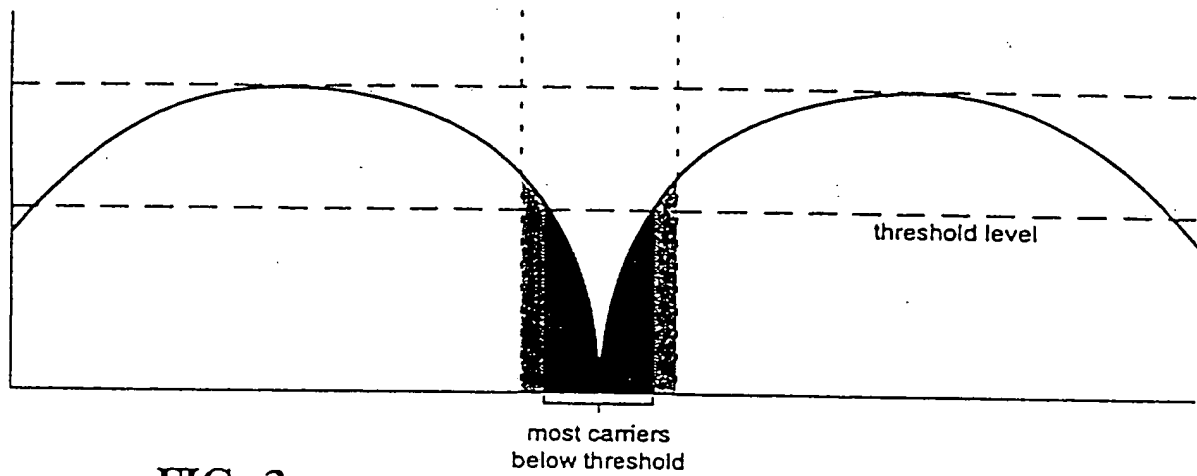
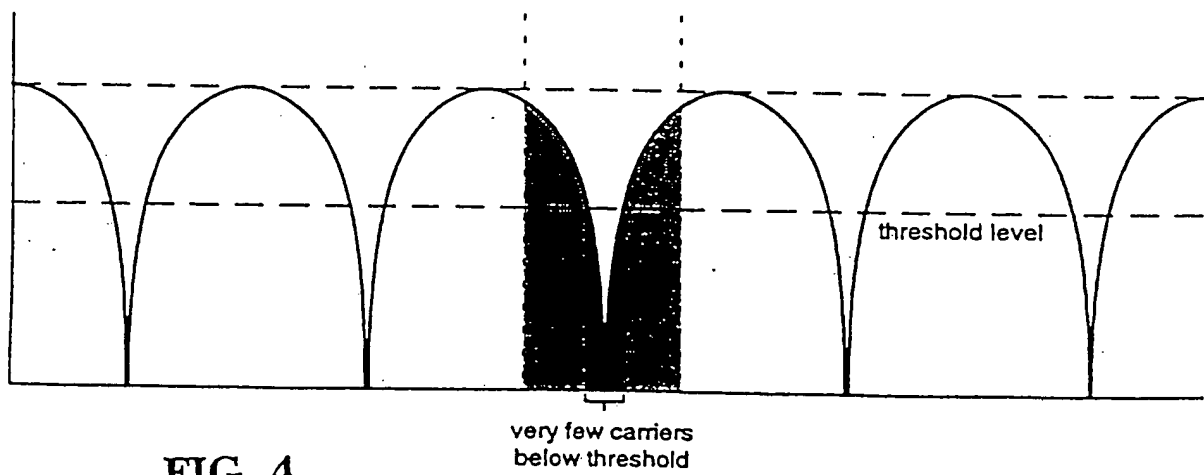


FIG. 5

*Short delay multipath***FIG. 3***Long delay multipath (using additional delay)***FIG. 4**

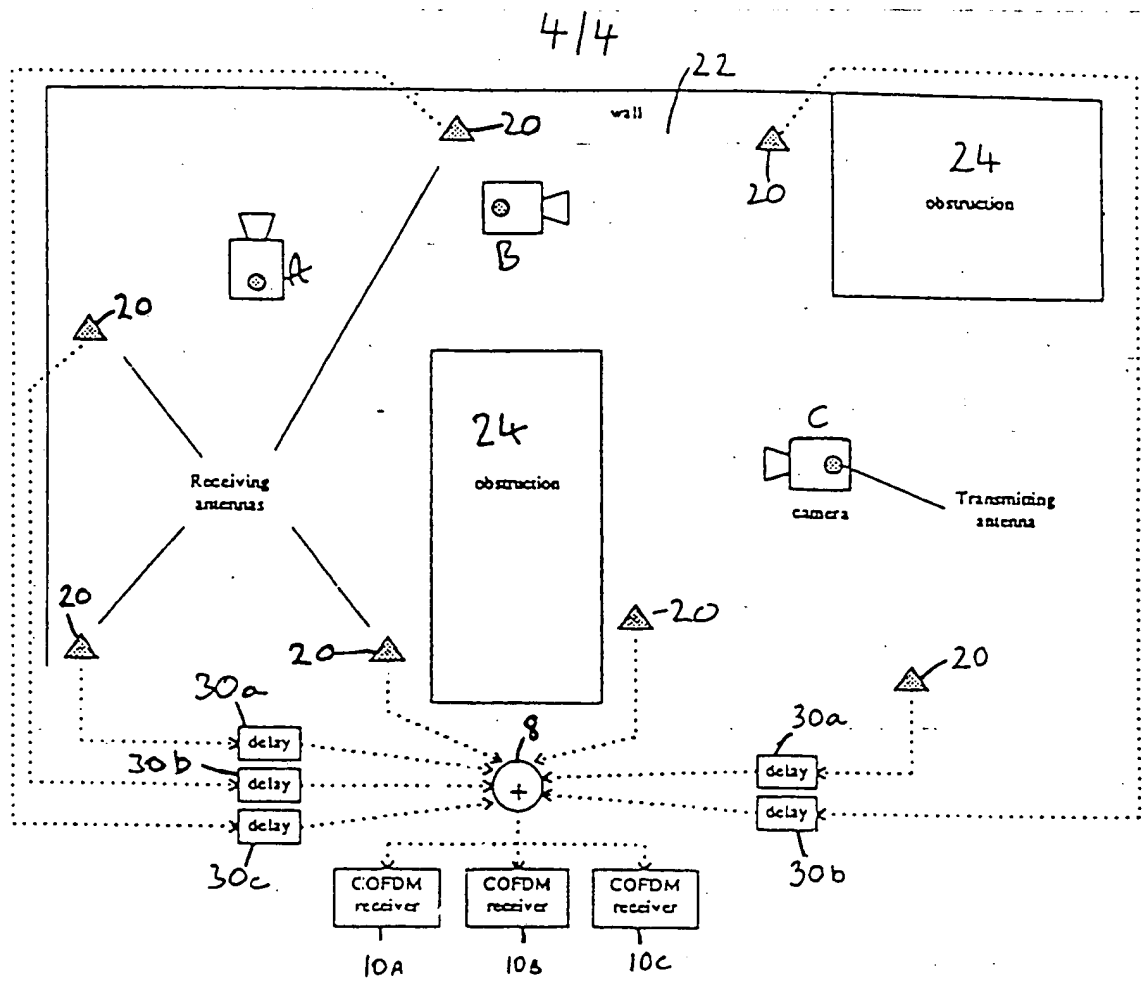


Fig. 6. An example DRUMS system

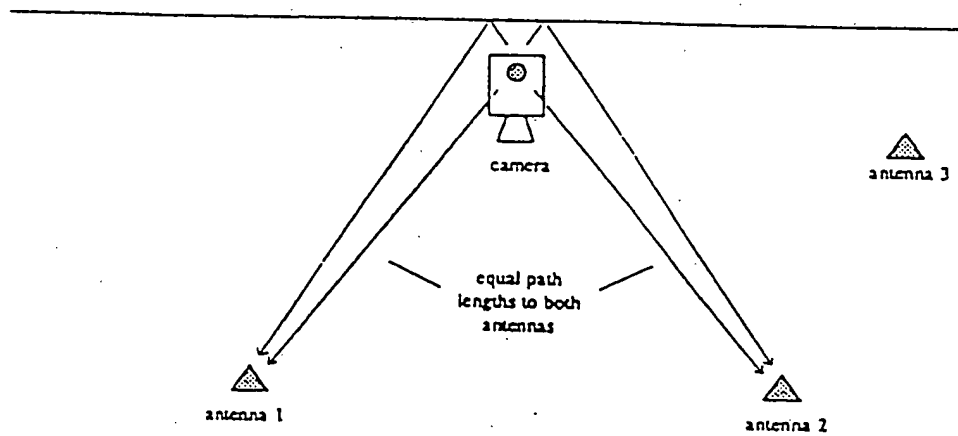


Fig. 7. Coincident flat fading at two antenna sites

Conventional digital diversity systems rely on complex receivers at each antenna to process the signal to help decide which antenna has the best reception. These systems tend to be prohibitably expensive.

5 Preferred embodiments of the present invention seek to provide a system for use with simple receivers in order to minimise cost and to simplify operational use. In particular, a preferred embodiment provides a diversity reception system using multi-antenna summation to provide a  
10 signal.

The invention is defined in its various aspects in the appended claims to which reference should now be made.

A preferred embodiment of the invention will now be described in detail by way of example with reference to the  
15 accompanying drawings in which:

Figure 1 is a block diagram of a radio camera in a diversity reception system with signal summation;

Figure 2 is a graph of the COFDM signal generated at the mobile camera of Figure 1;

20 Figure 3 is a graph showing the summed output of the adder in Figure 1 for a small delay between the signals received at the two antennas;

Figure 4 is equivalent to Figure 3 but is a result of including a longer delay between the signals on the two  
25 antennas;

Figure 5 is a block diagram of an embodiment of the invention;

Figure 6 is a block diagram of a second embodiment of the invention; and

30 Figure 7 shows a system where a third antenna is required to avoid flat fading of the signal.

A system called Coded Orthogonal Frequency Division Multiplexing (COFDM) has been developed for Digital Audio

The radio camera is likely to be used in situations, e.g., a football stadium, where the differential delays of the signal picked up at each receiving site are very small. This will cause the width of any fading notches to be  
5 large, and in some circumstances, all the carriers may be lost. For example, if the radio camera moved into a position almost exactly between two receiving antennas with cable feeds of equal length to the receiver decoder, almost all the carriers would be lost and no signal would be fed  
10 to the receiver decoder.

The type of fading which can occur is illustrated with reference to Figures 1, 2, 3 and 4. Figure 1 shows a radio camera 2 providing a COFDM signal to a pair of receive antennas 4 and 6. These in turn provide the  
15 received signals to an adder 8 which sends a summed output to a COFDM decoder.

The original COFDM ensemble of carriers generated at the radio camera is shown in Figure 2. As can be seen, all the carriers are of equal magnitude. Data is modulated  
20 onto these using a suitable modulation scheme, for example, quadrature phase shift-keying. It is of course the FFT of all these carriers which is transmitted by the camera.

Figure 3 shows the power distribution of the carriers after a reverse FFT at the COFDM decoder 10. This  
25 representation is for a small delay between the two COFDM signals. As can be seen, a large notch in the centre of the ensemble of carriers has been generated thereby losing much of the data.

In Figure 4, the same output is shown but for two  
30 signals with a much larger delay between them. The notch generated by multipath propagation is considerably narrower than in Figure 3 and thus there is sufficient data to use conventional error correction techniques to regenerate data lost in the notch.

At a complex location requiring many antennas, it is not necessary to give each antenna a unique delay. This is because the delays only need to be different for each area covered. Delay values can be re-used in different areas, providing the radio camera cannot transmit to two different antennas having the same delay as it moves from one area to the next. This avoids the problem of ending up with excessively large delays where a large number of antennas are used.

Such a system is illustrated in Figure 6. In this, a plurality of antennas 20 are provided in an area 22 bounded by a wall and having two obstructions 24. Three radio cameras are shown operating in this area and they are labelled A, B and C.

The receiving antennas 20 are all coupled to an adder 8 which provides output signals for three COFDM receivers 10, one for each radio camera.

Antennas which can not be seen by the same radio camera may have the same delay. Therefore, the two antennas 20 immediately adjacent obstruction 24 feed directly into the adder 8 with no delay. The other delays 30a, b and c are all different. However, it can be seen that two of the antennas 20 feed through a delay 30a. These again cannot be seen by one radio camera. Secondly, delays 30b cannot be seen by one radio camera. There is a final delay 30c connecting the final antenna 20 to the adder 8. The greatest delays would tend to be used in the most distant antennas to maximise effect.

An example of the technique will now be illustrated. In this example, it is assumed that a COFDM ensemble of 1,000 orthogonal carriers occupies a bandwidth of 20 MHz. This bandwidth is typical for current outside broadcast channels and will support nearly 100 Mbits per second using 64 QAM modulation (Quadrature Amplitude Modulation) a

ensemble is 20 MHz wide then  $\Delta f$  will be 10 MHz which, from the above equation, gives  $l = 10$  m.

A 10 m delay is equivalent to a time period of 33 ns which is only a small fraction of a symbol period of 50  $\mu$ s  
5 In practice, an extra delay equivalent to the physical separation between the antennas is required to ensure that the signals from the radio camera can still sum with the minimum permitted differential delay in any camera position. If an area, of say, 50 m by 50 m is covered by  
10 four antennas positioned around the edges, e.g., one at each corner of the square, then the differential delay line length should be about 60 m to maintain the minimum permitted delay. This is a maximum delay of 180 m for the fourth antenna. These distances are lengths for  
15 transmissions in vacuum and it is of course better to use delay time.

The delay required is short compared to video field synchronisation, which would still be corrected by a frame store synchroniser, as is usual with radio cameras. In  
20 DAB, an extra delay is deliberately introduced by time interleaving the data as a countermeasure against fading. Time interleaving can also be used in the radio camera system. However, the diversity reception arrangement is intended to continuously present sufficient carriers to the  
25 receiver through the delayed summation process.

The length of the required delays are too long to be implemented as cable delays as losses would be too high at the typical receive microwave frequencies. Down conversion of the receive signal at the antenna to lower the cable  
30 loss or for use with an SAW delay line could be arranged. An alternative is to up convert the signal to the infra-red band and use an optical fibre as both the delay element and the interconnection cable to the summing point.



delays, optical fibre delays, etc. It may be possible to  
down convert each antenna signal to produce very slightly  
different intermediate frequencies, thereby giving a  
continuously varying phase shift between them and sweeping  
5 any nulls across the pass band in the summed signal. This,  
combined with some limited time interleaving, may be of  
benefit.

At present, COFDM is limited to a gross bit rate of  
about 50 Mbits per second thereby suggesting a video bit  
10 rate of the order of 25 Mbits per second. However, the  
system does not have to be a full COFDM implementation.  
Other multicarrier or broad band techniques could be used.  
However, the application of VLSI techniques to COFDM may  
produce the compact circuitry required, possibly making it  
15 effective to obtain the required capacity by using two or  
more COFDM ensembles together.

transmitters provided, each transmitting signals in different parts of the frequency band.

7. A method of operating a digital radio communication system comprising a mobile transmitter and a plurality of receivers, the method comprising the step of  
5 transmitting digital signals from the transmitter, receiving the signals from the receivers, providing received signals to a summation means, and delaying the signals between the receivers and the summation means such  
10 that the effects of interference between signals are reduced.

8. A digital radio signal receiving system comprising a plurality of receivers each providing signals to a summation means, and delay means provided in at least  
15 all except one of the signal paths such that signals provided to the summation means may be delayed by different amounts to reduce the effects of interference between signals from two or more receivers.

9. A digital radio signal receiving system  
20 according to claim 8 in which the signals are COFDM signals.

10. A digital radio communication system substantially as herein described with reference to the accompanying drawings.

5. A digital radio communication system according to any preceding claim in which the transmitter transmits a COFDM signal.

6. A digital radio communication system according to any preceding claim in which there are a plurality of transmitters provided, each transmitting signals in different parts of the frequency band.

7. A digital radio communication system according to claim 1 in which the delay added to the signal received at each antenna has a minimum value equivalent to the maximum possible path difference between any two of the receiving antennas plus an extra delay.

8. A digital radio communication system according to claim 5 in which the maximum delay value used with one of the antennas is less than or equal to the guard interval of the COFDM signal being used.

9. A digital radio communication system according to claim 7 in which no extra delay is used with one of the antennas.

10. A digital radio communication system according to any preceding claim in which a connection means between the receiving antennas and the summation point also performs the delay function.

11. A digital radio communication system according to any preceding claim in which the received signal at each receiving antenna is converted to a different radio frequency or to an intermediate frequency or to an optical frequency to implement the delay using the appropriate connection means so that the connection means is more compact or the signal attenuation is lower.



Application No: GB 9725890.9  
Claims searched: 1-7

Examiner: Brian Ede  
Date of search: 22 April 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK CI (Ed.P): H4L(LDDRCP, LDDRCW, LDDRCX, LDDRQ, LDDRQX, LDDSX)  
Int CI (Ed.6): H04B 7/04 7/08 H04L 1/02 1/04 1/06  
Other: Online: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2259430 A (MOTOROLA) see Fig 1	1, 2, and 7
X	GB 2237706 A (RACAL) see Fig 3	1, 2, and 7
X	EP 0683571 A2 (SANYO) see 309-312 Fig 3	1, 3 and 7
X	EP 0575746 A1 (ALCATEL) see 10, 11 Fig 1	1, 2, and 7
X	WO96/08088A1 (MOTOROLA) see Fig 1	1, 2, and 7
X	WO91/20142A1 (MOTOROLA) see Fig 6	1, 3 and 7
X	US 5541963 (HITACHI) see Figs 3-5	1 and 7
X	US 4278978 (R A FROSCH) see Fig 1	1, 3 and 7

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.